Electron Energy Loss Spectrometry of 2D Plasmons:

A Feasibility Study of √3x√3 Ag on Si (111)

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Electron Energy Loss Spectroscopy (EELS) is a technique in which a beam of low-energy electrons, with a defined energy spread is targeted at a sample and the inelastically scattered electrons are measured to reveal energy losses. These losses provide information on energy band gaps as well as the concentration of free carriers in semiconductors. The area of 2D plasmons is one that provides great potential for semiconductors. If the angular velocity of a surface plasmon can be measured, then the electron density at the surface can be determined through the following formula: $\frac{1}{\sqrt{2}} * \frac{4\pi n e^2}{m*}$, where n is the electron density. In revolutionizing the semiconducting industry, as well as future sensing technology, the use of EELS to investigate 2D plasmons allows us to find the electron density at the surface, and further, it provides insight on how to tune the electron density.

Past studies[1] of the properties of 2D plasmons, using √3 x√3 Ag on Si (111), have claimed that n-type and p-type doping of the Si(111) does not change the phase velocity of the wave. However, the effect of drag on these waves, due to space charge at the Ag/Si interface, must be investigated further. In the Nagao experiment, this conclusion is drawn by comparing an Ag/Si system on both an n and p-type system, however, this will not influence drag, because it is not a change in concentration, just a change of sign in the charge barrier. Thus, our experiment proposes to investigate the effects of dopant levels of one doping type in order to see if dopant levels create a drag on the plasmon wave. If there is drag due to space charge, it will be seen as a change in the phase velocity of the wave.

The EELS system alone has not been used to investigate certain properties of two-dimensional plasmons. Thus, it is necessary to confirm the feasibility of this system as an accurate way of determining the properties of two-dimensional plasmons. Using the diffraction beams from 7x7 Si (111), the calibration of scattering k-space will be confirmed. This test also determines the resolution of the EELS system, placing all experimentation between the first and second diffraction beams (0.16 Å). In addition, because the cosine distribution of the scattering electrons is q-dependent, the angle of rotation necessary to perform these experiments was determined to be 30 degrees, the maximum angle of rotation of the EELS system.

Future experimentation will be threefold: EELS data taken on highly and lightly doped n-type Si, EELS data taken on Ag deposited on both a highly doped and a lightly doped Si substrate, and EELS data taken on magnetic dopants; all of which will help to determine the effect of space charge on the 2D plasmon wave. While plasmons are currently being used in bio, immuno, and gas sensing devices (surface plasmon polaritons), further research involving 2D plasmons will focus on coupling between thin films through surface plasmon modes and tunnel junction photodetectors.

[1]Nagao et al, "Dispersion and Damping of a Two-Dimensional Plasmon in a Metallic Surface-State Band." Physical Review Letters, Vol. 86: No.25: pp 5747-5750 (2001).